Foveated Non-line-of-sight Imaging

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Abstract: Existing non-line-of-sight imaging techniques suffer from a tradeoff between field of view and spatial resolution. We propose an imaging system that tackles this tradeoff by efficiently combining information from transient imaging and correlography subsystems. © 2020 The Author(s)

1. Introduction

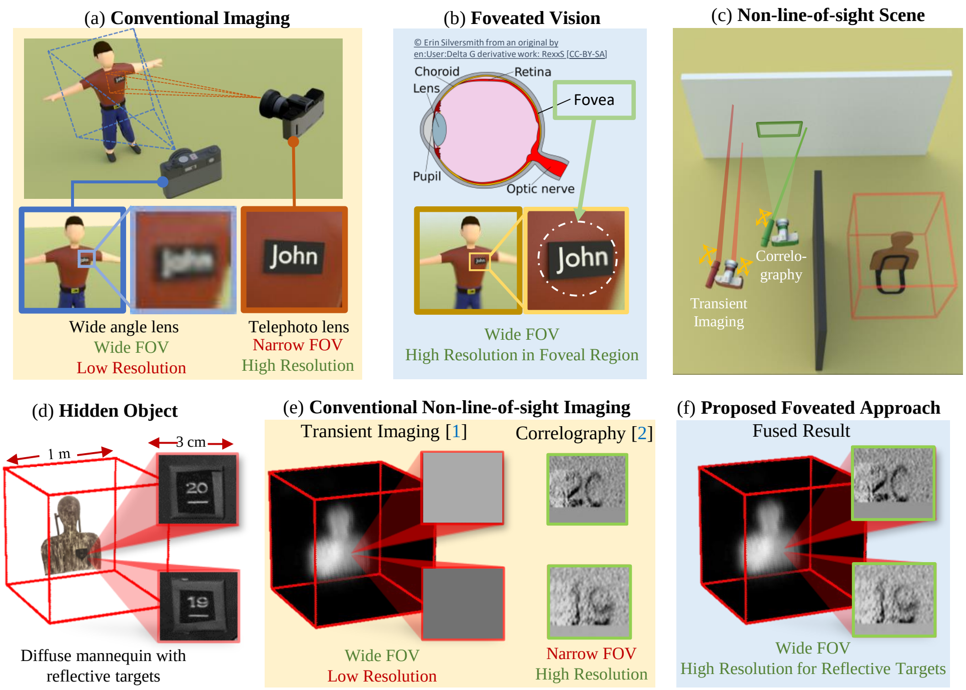

Fig. 1. Motivation for Foveated Non-line-of-sight Imaging

Classical imaging systems are inherently plagued by a tradeoff between the field of view (FOV) and spatial resolution. An imager can either sample the scene at exceedingly high resolution over a narrow field of regard or at coarsely-resolved points on a wider region (Fig. 1(a)). Attempts to overcome this tradeoff often take inspiration from nature, specifically the notion of foveated vision. Nature's elegant solution to the FOV-resolution tradeoff involves dense sampling of the received irradiance with a higher than usual concentration of photoreceptors in a small region of the retina, called the fovea. Such a foveated approach affords the ability to simultaneously localize objects in the scene and resolve fine spatial detail on objects of interest (see Fig. 1(b)). Literature is rife with examples of imaging systems that mimic foveated vision [1]. However, such capabilities are currently restricted to line of sight operation.

An exciting development in Computational Imaging is the notion of Non Line of Sight (NLoS) imaging [2], [3], [4]. Current approaches to NLoS imaging exploit the availability of an intermediary scattering surface (such as the wall in Fig. 1(c)) to indirectly illuminate the obscured object and intercept the light scattered by the obscured object. The first class of techniques (called Transient Imaging [2]) exploit the finite speed of light and rely on on the travel time of scattered light paths to reconstruct large objects in the hidden space, over a wide field of regard. However, the spatial resolution of these systems is limited to nearly $2cm$ at $1m$ standoff, as determined by the timing jitter of transient detectors. The second class of techniques (called correlography [4]) examine the spatial correlation in the scattered irradiance to recover a high-resolution image ($< 500\mu m$ resolution at $1m$ standoff) of centimeter-scale objects. Fig. 1(d) depicts experimental results from each of these techniques for the NLoS scene of Fig. 1(c). It is evident that NLoS imagers are also plagued by the same FOV-resolution tradeoff as LoS imagers.

Borrowing a cue from nature, we propose to address the FOV-resolution tradeoff in NLoS imaging by combining the best attributes of transient imaging and correlography. Our proposed foveated NLoS imager is comprised of two sub-systems: a wide FOV transient imager that is operable in confocal [3] and non-confocal mode and a second narrow FOV imager for correlography. We propose an imaging pipeline that communicates information from the wide FOV sub-system to the narrow FOV sub-system in an efficient manner. The output of the combined imager is a wide field-of-view 3D map of the hidden scene that contains high-resolution spatial information of highly reflective objects in the hidden scene. Fig. 1(f) depicts the experimental result from the proposed foveated NLOS imager for the hidden scene in Fig. 1(d).

2. Approach

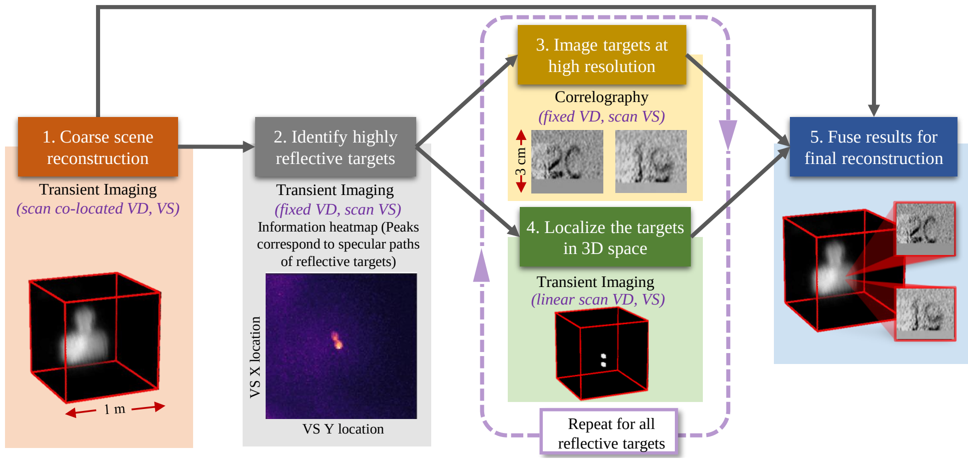

Fig. 2. Pipeline for foveated non-line-of-sight imaging

In the proposed foveated NLOS imager, the transient imaging sub-systems perform the role of peripheral vision by providing a coarse wide-field view of the hidden scene. The Correlography sub-system performs the role of foveal vision by imaging smaller reflective targets in the hidden scene at a high resolution. The process is illustrated in Fig. 2. The process begins with the use of confocal transient imaging to obtain a coarse estimate of the hidden scene (Step-1). We then use the non-confocal transient system to probe the hidden scene for regions containing highly reflective targets that are best suited for further interrogation using correlography (Step-2). The non-confocal transients are measured by fixing the imaging spot (also called virtual detector, VD) on the wall and scanning the laser spot (also called virtual source, VS). The maximum intensity of the recorded transients for each laser source position is interpreted as an information map. The peaks in the measured information map correspond to specular light paths originating at the source spot on the wall, bouncing off a reflective target in the scene, and terminating at the imaging spot. For each reflective target identified using the above step, we position the correlography laser and imaging spot to probe the corresponding specular path, and recover a high-resolution image of the target (Step-3). We additionally use the non-confocal transients to localize this reflective target in 3D (Step-4). Steps-3 and 4 are repeated for each reflective target in the hidden scene. The 3D location and high-resolution image of each reflective target are then fused into the coarse wide-field 3D map from Step-1 to obtain the final result.

3. Conclusion

Inspired by foveated vision, we propose an approach to address the FOV-resolution tradeoff in NLoS imaging. Our proposed NLoS imager produces a wide field-of-view 3D map of the hidden scene that contains high resolution spatial information of the highly reflective objects. Further analysis of the part on 3D localization of reflective targets, along with extensive testing of the foveated NLoS imager on a variety of scenes, is currently under progress.

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